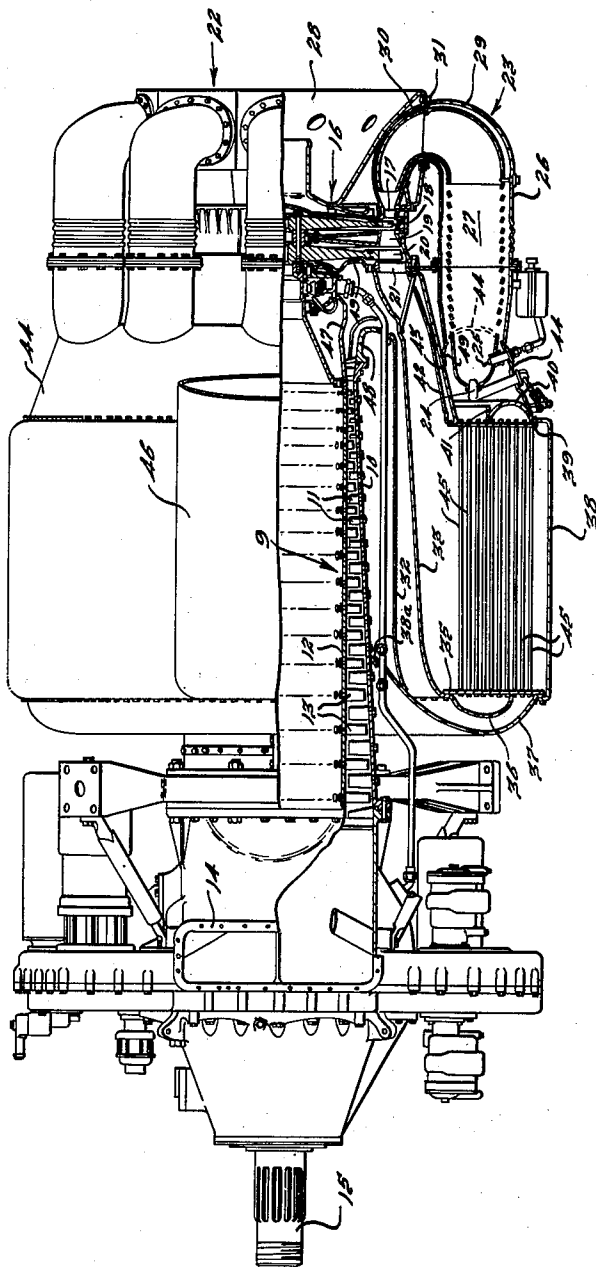


March 17, 1953

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GAS TURBINE POWER PLANT HAVING COAXIALLY
ARRANGED COMBUSTORS AND REGENERATOR
Filed Dec. 12, 1946

2,631,430



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UNITED STATES PATENT OFFICE

2,631,430

GAS TURBINE POWER PLANT HAVING CO-AXIALLY ARRANGED COMBUSTORS AND REGENERATOR

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Application December 12, 1946, Serial No. 715,840

9 Claims. (Cl. 60—39.37)

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This application relates to a power plant including a gas turbine, a burner apparatus for supplying combustion products to drive the turbine, and a compressor for supplying a combustion-supporting medium to the burner apparatus. More specifically, the invention relates to a novel and advantageous arrangement with the above elements of the power plant, of a heat exchanger for increasing the temperature of the combustion-supporting medium while on its way from the compressor to the burner apparatus by means of the combustion products while on their way from the turbine to exhaust.

It is known to employ the aforementioned elements in operative association as a power plant. There is considerable difficulty in arranging these elements suitably when the power plant is to be mounted upon an airplane for propelling the same. The power plant should be of a limited length, and yet width and breadth must be kept within satisfactory limits. We have invented an arrangement of the aforesaid power plant elements that satisfies the space requirements for use of the power plant in propelling aircraft.

An object of the present invention is to provide improvements in the arrangement of a compressor and a heat exchanger for changing the heat content of a medium compressed by the compressor.

A further object is to improve the arrangement of a gas turbine, a burner apparatus supplying the turbine, a compressor for supplying a combustion-supporting medium, and a heat exchanger utilizing the exhaust products from the turbine for heating the combustion-supporting medium. This arrangement may be used to advantage in an airplane.

Other objects will appear from the disclosure.

The single figure of the drawing is an elevational view partially in section of a power plant constructed and arranged according to the principles of the present invention. An axial compressor 9 comprises a stator 10 provided with blades 11 and a rotor 12 positioned within the stator 10 and provided with blades 13. The stator blades 11 and the rotor blades 13 are arranged in alternate stages. The compressor 9 has an inlet 14 for a combustion-supporting medium such as air and another similar inlet, not shown, which is on the opposite side of the machine. At the extreme left end of the power plant is located a shaft member 15 adapted drivingly to support a propeller, not shown. The shaft member 15 is axially aligned with the compressor 9,

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and is drivingly connected therewith by suitable means, not shown.

A gas turbine 16 is positioned to the right of the compressor 9 so as to be in axial alignment therewith and to drive the same and the shaft member 15 by suitable means, not shown. The turbine 16 comprises a stationary inlet blade stage 17, a first rotary blade stage 18, an intermediate stationary blade stage 19, a second rotary blade stage 20, and a stationary exhaust blade stage 21.

A burner apparatus 22 surrounds the turbine 16 and is made up of a plurality of burner devices 23. Each burner device comprises a nozzle 24 from which fuel under pressure is sprayed, an igniter 25, an outer tube 26, and an inner tube 27, which may be formed of nested frusto-conical sections as shown and claimed in the co-pending application of Samuel B. Williams, Serial No. 715,873, filed December 12, 1946, and now Patent No. 2,603,064. The outer tube 26 extends into an end member 28 and is formed of a section 29 external of the member 28 and a section 30 internal of the member 28. The sections 29 and 30 have suitable flange means by which they are joined to the member 28. The inner tube 27 is spaced from the outer tube 26, throughout their lengths, and this spacing is very small at the portions of the tubes within the end member 28.

A pair of generally cylindrical walls 32 and 33 are provided in radially outwardly spaced relation to the compressor 9. The walls 32 and 33 are spaced from one another and provide an annular passage for compressed gas delivered by the compressor 9. The outer wall 33 near its left end curves outwardly to a region of securement to the inner side of an annular header plate 35. Beyond this region the outer wall 33 has a portion 36, which extends away from the header plate 35, then radially outwardly and finally back toward the header plate where it is secured at a region spaced radially outward from the first region of securement. A ring-like end part 37 has an inner side appropriately attached to a flanged member 38^a, overlaps the wall 32 in sealing relation, and has an outer side secured to the outer side of the header plate 35. The end part 37 is spaced from the portion 36 of the wall 33 to form therewith a generally outwardly extending passage connected with the passage formed of the walls 32 and 33. A cylindrical sheath 38 is secured at one end to the end part 37 and to the header plate 35 at their outer region of securement and at the outer end to an annular header plate 39 and to the outer edge

of an end ring 40 which cooperates with the header plate 39. The inner edge of the end ring 40 is secured to a ring 41 which is secured to an intermediate region of the header plate 39. The inner edge of the header plate 39 is secured to annular walls 42 and 43. An annular wall 44 has one end secured to the juncture of the sheath 38 and the header plate 39 and the other end secured to the wall 43. The wall 44 has a plurality of openings, not indicated by reference characters, at which the various outer tubes 26 are joined to the wall 44, and through which the inner tubes 27 pass. A plurality of tubes 45, are secured to and extend through the header plates 35 and 39. The outer sheath 38 is provided with an outlet 46, and another similar outlet, not shown, which is on the other side of the sheath 38. The two outlets are generally in line with the two inlets 14.

In operation of the above described machine a combustion-supporting medium such as air is taken in through the inlets 14 and is then compressed by the compressor 9 while passing lengthwise thereof between the rotor 12 and the stator 10. The compressed air is discharged from the compressor through an annular passage formed by an inner wall 47 and an outer wall 48, which is really an extension of the wall 32. An end wall 49 forming part of the turbine 16 in effect connects the walls 47 and 33 so that the air moving to the right between the walls 47 and 48 is caused to turn and to move to the left between the walls 32 and 33. Thereafter, the air moves outwardly between the end member 37 and the wall portion 36. Then the air passes the length of the bundle of the tube 45 three times, first by moving to the right through the outer tubes 45 connecting the space between member 37 and wall portion 36 and the space within the end ring 40. Then the air moves to the left through intermediate tubes 45 connecting the space within the end ring 40 and the space within the wall portion 36. Then the air passes to the right through the inner tubes 45, whence it passes into the various outer tubes 26.

Thereafter the air passes through the walls of the tubes 27 to support combustion of fuel coming from the nozzles 24 and ignited by the igniters 25. The gaseous products resulting from the combustion are discharged from the various inner tubes into the various stationary and rotary stages of the turbine 16 causing it to rotate. Some air will also be directed into the turbine, since there is some spacing between the inner tube 27 and the outer tubes 26 throughout their lengths. After the air and combustion products leave the turbine 16, they pass between the walls 32 and 42 and are directed against the exteriors of the tubes 45. The air and combustion products pass across the tubes, thus preheating the air passing back and forth through the tubes, and are discharged through the outlets 46. Since the inlets 14 and the outlets 46 are longitudinally arranged, there is a minimum of aerodynamic disturbance.

It is to be noted that the air as it passes back and forth between the compressor and the burner apparatus is kept in an annular path, and thus there is a minimum of disturbance of the annular discharge of air from the compressor.

The tubes 45 and associated end members and walls constitute an effective crossflow-counterflow heat exchanger whereby the waste heat of the products exhausted from the turbine 16 is employed to preheat the air destined to support

combustion of the fuel in the tubes 27. By arranging the heat exchanger so as to make it surround the compressor, we have accomplished an efficient and advantageous relative positioning of the parts of the entire machine so that the machine occupies a minimum of space. Saving of space is important when the machine is put to aircraft use. It is necessary to keep the length of the machine within limits. Also it is necessary to restrict its width and breadth. This has been accomplished by placing the heat exchanger so that it surrounds the compressor and also by making the burner tubes surround the turbine.

We claim:

1. The combination with a compressor, a turbine driving the same and axially aligned therewith, and a burner apparatus surrounding the turbine and adapted to convert fuel and a combustion-supporting medium compressed by the compressor to combustion products and to pass the same to the turbine for driving the turbine; of conduit-forming wall surrounding the compressor and defining coaxial annular passages one within another connected respectively to the compressor and to the turbine, and a heat exchanger connected to and surrounding the said walls and communicating with said annular passages in a manner for passing the combustion-supporting medium from the compressor to the burner apparatus and increasing the temperature of the medium by receiving and passing the combustion products from the turbine to exhaust, said heat exchanger including a plurality of straight tubes extending axially of the compressor, and arranged in an annulus connected to the said walls surrounded by the heat exchanger for passing the combustion-supporting medium the length of the tubes three times for assuring good absorption from the combustion products coming from the turbine and passed over the tubes.

2. In a compact gas-turbine power plant, the combination with a reference annular discharge casing surrounded by another annular discharge casing, and a ring-like part adjacent one end of said casings in semi-toric radiating relation, of an annular crossflow-counterflow regenerator radially spaced from and around said casings in coaxial relation, said regenerator extending from said ring-like part in a certain direction parallel to said axis and comprising a plurality of bundles of tubes, a pair of disk-like headers in axial spacing substantially from the ring-like part for the extent of the regenerator, the ends of the bundles being so constructed and arranged for support in the headers as mutually to form successive enveloping annuli, said reference annular discharge casing being adapted to provide a passage extending in a direction opposite to said certain direction and said ring-like part connecting the outlet end of the discharge casing with the outermost annulus of the regenerator thereby to produce a path reversal resulting in a flow path through the tubes of said outermost annulus in said certain direction, and a housing having end members and radial and axial openings, the end members cooperating in affording a path reversal upon inwardwise progression from annulus to annulus whereby the paths defined by the tube bundles alternate respectively from said certain direction to said opposite direction, the innermost annulus defining a path extending in said certain direction and communicating with said axial opening, said other annular discharge casing terminating at said radial opening

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and cooperating with the housing and headers to define a radiating path athwart said annuli, the exteriors of the tubes presenting exposed surface areas within said radiating path.

3. In gas turbine propulsion apparatus of the type including an axial flow compressor unit having impeller elements moving in an annular chamber of which the mean radius is relatively short and substantially constant throughout the length thereof, and a turbine unit having bucket elements coaxial with said impeller elements, said bucket elements moving in an annular chamber in axial spacing to said impeller annular chamber and of which the mean radius is relatively longer and substantially constant throughout the length thereof, the compressor discharging relatively cool fresh air in the direction of the rear of the apparatus and the turbine discharging relatively warm spent gases axially in the direction of the front of the apparatus, the discharge openings of said units terminating substantially in a common transverse plane spaced from the ends of the apparatus, the combination of conduit forming walls surrounding the compressor and defining an annular chamber leading from the compressor discharge forwardly a length along the apparatus, radially outward, thence rearwardly a length, an annular regenerator occupying the outer portion of the radial gap between said forward and rearward lengths, the regenerator defining an outer axially rearward path leading from said rearward length to a header end, a parallel codirectional and coterminous path leading from a header end to a regenerator discharge, and an interposed path connecting said header ends, the interposed path and the parallel paths describing a passage threading radially inwardly in S-configuration, and a collector casing structure defining an annular chamber extending from the inner portion of the radial gap between said forward and rearward lengths and leading from the turbine discharge forwardly a distance along said forward length, radially outward and athwart said S-configuration thence rearwardly to a collector casing discharge, the regenerator discharge and the collector casing discharge being so constructed and arranged as to terminate substantially in said common transverse plane in respective order radially outward of said turbine discharge.

4. A gas turbine propulsion apparatus having an air intake at the front thereof and comprising in coaxial sequence thereafter a frustum-like cylindrical casing surrounding an axial flow compressor of a certain mean blade radius, a frustum-like cylindrical casing surrounding an axial flow turbine of a certain larger mean blade radius, and an additional frustum-like casing surrounding an annular chamber of substantially said certain larger mean radius, in the combination with a bell sheet within said last named casing, said bell sheet flaring rearwardly to a peripheral junction along the rear edge of the casing, said annular chamber being bounded on its front side by the turbine and on its inner and rear sides by the bell sheet, a plurality of tubular combustion means disposed circumferentially around said casings and being axially coextensive with at least a portion of each casing, and a shell means forming an intermediate compressed air chamber enveloping said compressor casing in discharge receiving relation, the intake ends of said tubular combustion means each communicating with said intermediate chamber, of a conduit means establishing communication between

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the discharge ends of said tubular combustion means and said turbine casing, the conduit means having an elbow portion extending rearwardly in continuation of the tubular configuration of the burner means and thence radially inwardly to said additional frustum-like casing, each companion elbow and tube being disposed with their axes in coaxial radial planes, said conduit means further having a transition means connecting with the elbow portion and extending inwardly through said annular chamber contiguous with said bell sheet and thence forwardly to an annular connection with the turbine casing, said shell means, burner means, conduit means, and turbine being disposed in effectively an overlapping spiral sequence providing a path for air and products of combustion through the apparatus necessitating an ultimate cross of flow.

5. A gas turbine propulsion apparatus having an air intake at the front thereof and comprising in coaxial sequence thereafter a frustum-like cylindrical casing surrounding an axial flow compressor of a certain mean blade radius, a frustum-like cylindrical casing surrounding an axial flow turbine of a certain larger mean blade radius, and an additional frustum-like casing surrounding an annular chamber of substantially said certain larger mean radius, in the combination with a bell sheet within said last named casing, said bell sheet flaring rearwardly to a peripheral junction along the rear edge of the casing, said annular chamber being bounded on its front side by the turbine and on its inner and rear sides by the bell sheet, a plurality of tubular combustion means disposed circumferentially around said casings and being axially coextensive with at least a portion of each casing, and a shell means forming an intermediate compressed air chamber enveloping said compressor casing in discharge receiving relation, the intake ends of said tubular combustion means each communicating with said intermediate chamber, of a conduit means establishing communication between the discharge ends of said tubular combustion means and said turbine casing, the conduit means having an elbow portion extending rearwardly in continuation of the tubular configuration of the burner means and thence radially inwardly to said additional frustum-like casing, each companion elbow and tube being disposed with their axes in coaxial radial planes, said conduit means further having a transition means connecting with the elbow portion and extending inwardly through said annular chamber contiguous with said bell sheet and thence forwardly to an annular connection with the turbine casing, said shell means, burner means, conduit means, and turbine being disposed in effectively an overlapping spiral sequence providing a path for air and products of combustion through the apparatus necessitating an ultimate cross of flow, each combustion means and companion conduit means having an inner liner in spaced relation to form a sleeve-like air inlet passage therebetween and a burner passage therewithin, the walls of both the air inlet passage and burner passage respectively progressing in constant spaced relation as along the combustion means and in converging relation as along the elbow portion and transition means of the conduit means.

6. In gas turbine propulsion apparatus of the type including an axial flow compressor unit having impeller elements moving in an annular chamber of which the mean radius is relatively short and substantially constant throughout the

length thereof, and a turbine unit having bucket elements coaxial with said impeller elements, said bucket elements moving in an annular chamber in axial spacing to said impeller annular chamber and of which the mean radius is relatively long and substantially constant throughout the length thereof, the compressor discharging relatively cool fresh air in the direction of the rear of the apparatus and the turbine discharging relatively warm spent gases axially in the direction of the front of the apparatus, the discharge openings of said units terminating substantially in a common transverse plane spaced from the ends of the apparatus, the combination of annular conduits one within the other connected to the respective discharge openings of said units and having ends extending away from said common plane in the axial direction of the compressor with respect to said apparatus, an annular regenerator surrounding said compressor unit and being formed with annular openings connected to said annular conduits for receiving the cool fresh air and warm spent gases, a ring of tubular burners connected to the regenerator and to the turbine unit and in a general disposition about the latter, and collector casing structure surrounding the regenerator for receivingly collecting the warm spent gases after use through the regenerator in heating the air.

7. In gas turbine propulsion apparatus of the type including an axial flow compressor unit having impeller elements moving in an annular chamber of which the mean radius is relatively short and substantially constant throughout the length thereof, and a turbine unit having bucket elements moving in an annular chamber in axial spacing to said impeller annular chamber and of which the mean radius is relatively long and substantially constant throughout the length thereof, the compressor discharging relatively cool fresh air in the direction of the rear of the apparatus and the turbine discharging relatively warm spent gases axially in the direction of the front of the apparatus, the discharge openings of said units terminating substantially in a common transverse plane spaced from the ends of the apparatus, the combination of annular conduits one within the other connected to the respective discharge openings of said units and having ends extending away from said common plane in the axial direction of the compressor with respect to said apparatus, an annular regenerator including an annulus of axially extending tubes surrounding said compressor unit, said regenerator being formed with annular openings connected to said annular conduits for receiving the cool fresh air and warm spent gases, a ring of tubular burners connected to the regenerator and to the turbine unit in a general disposition about the latter, and collector casing structure surrounding the regenerator for receivingly collecting the warm spent gases after passage across the annulus of tubes in heating the air.

8. An elastic-fluid-utilizing propulsion apparatus comprising in combination an axial flow compressor unit, a gas turbine unit drivingly connected to the compressor unit and being coaxially arranged such that their relatively nearer ends are the discharge ends of the respective units, a ring of burners surrounding the turbine unit, an annular regenerator surrounding the compressor unit in spaced relation with respect thereto and having a burner supply opening in transverse alignment in communication with the ring of

burners, and a pair of coaxial walls arranged generally one within another with an annular space between, the outer of said walls having the ends thereof connected respectively to the turbine and to the annular regenerator and forming one side of a turbine exhaust gas path, the inner of said walls having the ends thereof connected respectively to the compressor and to the annular regenerator and forming one side of a compressed air path, and a wall within said annular space coaxial with respect to and cooperating with the outer and inner walls respectively to form the opposite side of each of said turbine exhaust gas and compressed air paths for uniformly supplying the elastic fluids to the regenerator in annular paths.

9. An elastic-fluid-utilizing propulsion apparatus comprising in combination an axial flow compressor unit, a gas turbine unit drivingly connected to the compressor unit and being coaxially arranged such that their relatively nearer ends are the discharge ends of the respective units, a ring of burners surrounding the turbine unit, an annular regenerator surrounding the compressor unit in spaced relation with respect thereto and having a burner supply opening in transverse alignment in communication with the ring of burners, a pair of coaxial walls arranged generally one within another with an annular space between, the outer of said walls having the ends thereof connected respectively to the turbine unit and to the annular regenerator and forming one side of the turbine exhaust gas path, the inner of said walls having the ends thereof connected respectively to the compressor unit and the annular regenerator and forming one side of a compressed air path, and a wall within said annular space coaxial with respect to and cooperating with the outer and inner walls respectively to form the opposite of each of said turbine exhaust gas and compressed air paths for uniformly supplying the elastic fluids to the regenerator in annular paths, said annular regenerator containing a plurality of straight tubes extending axially of the compressor unit and arranged in a bundle defining a cylindrical path of revolution within said annular regenerator, said annular regenerator being connected in the above described manner to the aforesaid walls and surrounding the same for passing the compressed air the length of the tubes three times for assuring good absorption from the exhaust gases coming from the turbine and passed over the tubes.

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